REMARKS

This Preliminary Amendment cancels, without prejudice, claims 1 to 13 in the underlying PCT Application No. PCT/DE2004/000809 and adds new claims 14 to 28. The new claims, inter alia, conform the claims to United States Patent and Trademark Office rules and does not add any new matter to the application.

In accordance with 37 C.F.R. § 1.125(b), the Substitute Specification (including the Abstract) contains no new matter. The amendments reflected in the Substitute Specification (including Abstract) are to conform the Specification and Abstract to United States Patent and Trademark Office rules or to correct informalities. As required by 37 C.F.R. §§ 1.121(b)(3)(ii) and 1.125(c), a Marked-Up Version of the Substitute Specification comparing the Specification of record and the Substitute Specification also accompanies this Preliminary Amendment. Approval and entry of the Substitute Specification (including Abstract) are respectfully requested.

The underlying PCT Application No. PCT/DE2004/000809 includes an International Search Report, dated September 1, 2004, a copy of which is included. The Search Report includes a list of documents that were considered by the Examiner in the underlying PCT application.

The underlying PCT Application No. PCT/DE2004/000809 also includes an International Preliminary Examination Report, dated August 17, 2005. An English translation of the International Preliminary Examination Report and is included herewith.

It is respectfully submitted that the subject matter of the present application is new, non-obvious and useful. Prompt consideration and allowance of the application are respectfully requested.

Respectfully submitted,

KENYON & KENYON

Dated: Nov. 17, 2005

By: Clif Ulri

Clifford A. Ulrich
Reg. No. 42,194
One Broadway
New York, New York 10004
(212) 425-7200
CUSTOMER NO. 26646

10/557625

IAP20 Rec'd PCT/PTO 17 NOV 2005

[10537/311]

METHOD FOR CUTTING FREEFORM SURFACES, CUTTING TOOL AND USE OF THE CUTTING TOOL

FIELD OF THE INVENTION

The present invention relates to a method for cutting freeform surfaces ~~according to the preamble of Claim 1. Furthermore, the present invention relates~~, to a cutting tool ~~according to the preamble of Claim 10~~ and to the use of the cutting tool.

The present invention relates to the area of cutting technology, ~~particularly~~ **e.g.,** to HSC cutting (high-speed cutting), which is also ~~known~~ **referred to** as HPC cutting (high performance cutting).

BACKGROUND INFORMATION

~~According to the related art~~ **Conventionally**, so-called spherical cutters are used for cutting freeform surfaces. Such spherical cutters have a tool shank and a tool head attached to the tool shank, a radius of the tool head corresponding to a radius of the tool shank in the spherical cutter. The tool head therefore does not protrude laterally beyond an outer lateral surface of the tool shank.

For minimizing undesired residual lines formed during cutting, the use of a spherical cutter entails restrictions with respect to the line spacing to be maintained between the cutting paths of the cutting tool. This results in a relatively high number of required cutting paths, which determines the time required for cutting. From the point of view of high-speed cutting or high-performance cutting, however, short cutting times ~~are~~ **may be** desirable.

SUMMARY

~~Using this as a starting point, the present invention is based on the objective of providing a novel method for cutting freeform surfaces, a novel cutting tool as well as a use of the cutting tool.~~

~~This objective is achieved in that the method, named at the outset, for cutting freeform surfaces is refined by the features of the characterizing part of Claim 1.~~

[[A]] **According to an example embodiment of the present invention, a** workpiece is cut by a cutting tool [[in]] such ~~a way~~ that a desired freeform surface [[is]] **may be** obtained. For cutting purposes, the cutting tool is moved along at least one defined cutting path relative to the workpiece. ~~According to the present invention, a~~ **A** cutting tool (a so-called special cutter) is used, the tool head of which has a greater radius than a tool shank of the cutting tool, without, however, the tool head protruding laterally beyond an outer lateral surface of the tool shank. This ~~has the advantage~~ **may provide** that cutting results in low residual line formation. Accordingly, it [[is]] **may be** possible to increase the line spacing during cutting and reduce the time required for cutting.

~~According to an advantageous refinement of the present invention, first~~ **First** cutting paths [[are]] **may be** produced by using a spherical cutter, its radius of the tool head corresponding to the radius of the tool shank. From these first cutting paths, second cutting paths are produced for the cutting tool to be used, the tool head of which has a greater radius than a tool shank of the same. This ~~allows~~ **may allow** for a particularly simple and quick production of the cutting paths for the cutting tool to be used. This ~~advantageous~~

~~refinement is~~ **may be** used when the CAM system used does not support special cutters.

~~The cutting tool according to the present invention is characterized by the features of Claim 10. The use of the cutting tool according to the present invention is defined in Claim 13.~~

~~Preferred further developments of the present invention are revealed by the dependent claims and the following description.~~

~~An exemplary embodiment~~ **Example embodiments** of the present invention [[is]] **are** explained in **more** detail ~~in light of the drawings, without being limited to this. The figures in the drawing show:~~ **below with reference to the appended Figures.**

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1[[:]] **illustrates** a **conventional** cutting tool ~~according to the related art~~ in a side view~~; and~~**.**

Figure 2[[:]] **is a side view of** a cutting tool according to **an example embodiment of** the present invention ~~in a side view~~.

DETAILED DESCRIPTION

~~In the following,~~ **Example embodiments of** the present invention ~~will be~~ **are** described in greater detail **below** with reference to the ~~figures~~ **appended Figures**. Before presenting the details of [[the]] **a** method ~~of the present invention~~ **hereof** and of [[the]] **a** cutting tool ~~of the present invention~~ **hereof**, however, a few ~~concepts~~ **aspects**, to which reference will be made later, shall be ~~defined~~ **mentioned** below.

When cutting a workpiece to be machined, the surface of the workpiece is to obtain a desired three-dimensional geometry.

This desired three-dimensional geometry on the surface of the workpiece is also ~~called~~ **referred to as** a freeform surface.

The cutting of the workpiece to be machined occurs with the aid of a cutting tool, a so-called cutter. For purposes of machining the workpiece, the cutting tool or cutter is moved relative to the workpiece. The movement of the cutting tool or cutter relative to the workpiece is described by so-called tool coordinates, the tool coordinates defining the position of a tool reference point. The movement of the tool reference point in cutting the workpiece is ~~called~~ **referred to as** the tool path or cutting path.

The cutting tool has a tool shank as well as a tool head attached to the tool shank. When cutting, the tool head comes into contact with the workpiece to be machined. The properties of a cutting tool are determined by several geometric parameters that are generally specified in a tool coordinate system. This tool coordinate system originates in the tool reference point, in which an axis or axis of symmetry of the tool shank intersects with one end or one tip of the tool head. Starting from this origin of the tool coordinate system, a first axis of the same ~~runs~~ **extends** in the direction of the axis of symmetry of the tool shank. The remaining axes of the tool coordinate system each ~~run~~ **extend** perpendicular with respect to the latter.

The parameters by which the properties of a cutting tool are defined in the tool coordinate system are ~~in particular~~**, e.g.,** a diameter or radius of the tool shank, a diameter or radius of the tool head, a horizontal coordinate of a radius center point of the tool head as well as a vertical coordinate of the radius center point of the tool head**, etc**. Parameters such as angles between line segments and horizontal or vertical axes of the cutting tool are possibly included as well, the

vertical axis ~~running~~ **extending** in the direction of the tool axis and the horizontal axis ~~running~~ **extending** perpendicularly with respect to this tool axis of the cutting tool.

The cutting of a workpiece for producing a defined three-dimensional freeform surface occurs by so-called five-axes cutting. In five-axes cutting, the cutting tool may be moved along five axes relative to the workpiece to be machined. Three axes are used for the linear movement of the cutting tool relative to the workpiece such that every point in space may be accessed. In addition to this linear movement along the so-called linear axes, the cutting tool may also be moved around a swivel axis as well as a tilting axis for undercutting. Rotational movements of the cutting tool are possible along the swivel axis as well as the tilting axis. This makes it possible to access all points in space without collision. The swivel axis as well as the tilting axis are ~~frequently~~ also generally ~~called~~ **referred to as** rotary axes.

Figure 1 ~~shows~~ **illustrates** a **conventional** cutting tool 10 ~~as it is known from the related art and at it is~~ **that may be** used in accordance with ~~the related art~~ **conventional systems** for cutting freeform surfaces on workpieces.

Cutting tool 10 as ~~shown~~ **illustrated** in Figure 1 has a tool shank 11 as well as a tool head 12 attached to tool shank 11. Tool shank 11 has a diameter d_S and a radius r_S, where $r_S=d_S/2$. Tool head 12 has a radius r_K, radius r_K of tool head 12 corresponding to radius r_S of tool shank 11 in the case of the cutting tool ~~shown~~ **illustrated** in Figure 1. Accordingly, for cutting tool 10 [[of]] **illustrated in** Figure 1, rK=rS=dS/2. Such a cutting tool is also ~~called~~ **referred to as** a spherical cutter. As ~~can be gathered from~~ **illustrated in** Figure 1, tool head 12 does not protrude laterally beyond an outer lateral surface of tool shank 11.

Figure 1 furthermore ~~shows~~ **illustrates** an axis 13 of tool shank 11. Axis 13 of tool shank 11 intersects one end or one tip of tool head 12 at a point 14, point 14 forming a point of origin for a tool coordinate system.

Figure 2 ~~shows~~ **illustrates** a cutting tool 15 according to **an example embodiment of** the present invention. Cutting tool 15 ~~according to the present invention in turn has~~ **includes** a tool shank 16 and a tool head 17 attached to tool shank 16. Furthermore, Figure 2 ~~again shows~~ **illustrates** an axis or axis of symmetry 18 of tool shank 16 as well as a point 19, at which axis of symmetry 18 of tool shank 16 intersects one end or one tip of tool head 17.

~~In accordance with the present invention, a~~ **A** radius R_K of tool head 17 is greater than a radius R_S of tool shank 16. Therefore: $R_K>R_S$. Also in cutting tool 15 ~~according to the present invention~~, tool head 17 does not protrude laterally beyond an outer lateral surface of tool shank 16.

As ~~can be gathered from~~ **illustrated in** Figure 2, radius R_K of tool head 17 is ~~clearly~~ greater than radius R_S of tool shank 16, ~~particularly~~ **e.g.,** greater than the double radius R_S of tool shank 17 or its diameter D_S. Therefore: $R_K>>R_S$.

Thus, Figure 2 ~~shows~~ **illustrates** that a radius center point 20 of tool head 17 of cutting tool 15 ~~according to the present invention~~ does ~~no longer~~ **not** lie in a region of the tool shank, as in the case of spherical cutter 10 ~~shown~~ **illustrated** in Figure 1, but rather outside of the same. The position of radius center point 20 is determined by a horizontal coordinate E and a vertical coordinate F in the tool coordinate system, a point of origin of this tool coordinate system lying in point 19.

~~At this point it~~ **It** should be noted that although radius R_K of tool tip 17 is ~~in any event~~ greater than radius R_S of tool shank 16, it is however smaller than a smallest radius of curvature of the freeform surface to be cut. This ~~ensures~~ **may ensure** ~~on the one hand~~ that there is a low residual line formation and that the line spacing during cutting is thereby increased and the cutting time reduced. On the other hand, collision-free machining of the workpiece [[is]] **may be** ensured.

~~According to the present invention, cutting~~ **Cutting** tool 15 ~~of the present invention is~~ **may be** used for manufacturing rotationally symmetric, disk-shaped or ring-shaped components. These components [[are]] **may be** rotor disks having integrated blading, i.e.**,** so-called bladed disks, which are also referred to as blisks. These [[are]] **may be** used in aircraft engines.

Furthermore, ~~a new~~ method ~~according to the present invention~~ for cutting freeform surfaces ~~on workpieces is to~~ **may** be provided ~~by the present invention~~ **hereby**. When cutting freeform surfaces, cutting tool 15 cuts a workpiece [[in]] such ~~a way~~ that the desired freeform surface [[is]] **may be** obtained. For this purpose, cutting tool 15 is moved along several defined cutting paths relative to the workpiece ~~(not shown)~~. ~~According to the present invention, cutting~~ **Cutting** tool 15 as ~~shown~~ **illustrated** in Figure 2 [[is]] **may be** used.

~~In accordance with an advantageous refinement of the method according to the present invention, first~~ **First** cutting paths as ~~shown~~ **illustrated** in Figure 1 [[are]] **may be** produced in a first step with the aid of spherical cutter 10 if a CAM system used does not support special cutters. ~~In the case of~~ **For** spherical cutter 10 as ~~shown~~ **illustrated** in Figure 1, radius r_K of tool head 12 corresponds to radius r_S or half of diameter d_S

of tool shank 11. Spherical cutters 10 ~~of this kind~~ are ~~in any event~~ supported by ~~the~~ **a conventional** CAM system ~~as it is known from the related art~~. From these first cutting paths, second cutting paths are ~~then~~ produced in a second step for the specific cutting tool to be used, whose radius R_K of tool head 17 is greater than radius R_S of its tool shank 16. The cutting tool ~~specifically~~ to be used ~~is thus the special~~ **may be a** cutter ~~in accordance with the present invention~~ **hereof**.

Normal vectors of the workpiece surface to be cut are produced for ascertaining the second cutting paths for cutting tool 15 to be used from the first cutting paths that were produced by using spherical cutter 10. The first cutting paths ~~are made up of~~ **include** a plurality of support points, a normal vector of the workpiece surface to be cut being produced for each support point of the first cutting paths. For producing the second cutting paths for the specific cutting tool 15 to be used, the support points of the first cutting paths are shifted relative to the corresponding normal vectors, that is, in the direction of the normal vectors. For this purpose, the support points are shifted by the difference between radius r_K of tool head 11 of spherical cutter 10 and radius R_K of tool head 17 of the cutting tool 15 ~~of the present invention~~ actually to be used. Expressed in other words, the support points are shifted [[in]] such ~~a way~~ that a point of contact of the cutting tool 15 to be used on a surface of the workpiece to be cut corresponds to the point of contact of spherical cutter 10 and is always in the region of the radius of the tool head of the cutting tool 15 to be used.

In this shifting of the support points, the coordinates that describe the position of the radius center point 20 of tool head 17 of cutting tool 15 ~~of the present invention~~ are taken into account. As already mentioned above, this radius center point 20 of cutting tool 15 ~~according to the present invention~~

no longer lies on axis 18, but is rather defined by horizontal coordinate E and around vertical coordinate F. On the basis of these characteristic quantities and the corresponding characteristic quantities of spherical cutter 10<u>,</u> it is possible to perform the shift of the support points.

Consequently, according to the method ~~of the present invention~~, first cutting paths are produced, ~~preferably~~ <u>**e.g.,**</u> in a first step, with the aid of a spherical cutter, the radius r_K of the tool head corresponding to the radius r_S of the tool shank. These first cutting paths serve as ancillary cutting paths. ~~For according to the present invention it~~ <u>**It**</u> is not a spherical cutter that is to be used, but rather a cutting tool ~~according to the present invention~~ in which the radius R_K of the cutter head is greater than the radius R_S of the cutter shank, without however the tool head laterally protruding beyond an outer lateral surface of the tool shank. ~~Of course, the~~ <u>**The**</u> ancillary cutting paths are produced with the aid of a spherical cutter in which the radius r_S of the cutter shank corresponds to the radius R_S of the cutter shank of the tool ~~of the present invention~~ actually to be used. The actual cutting paths for the cutting tool ~~of the present invention~~ are ~~then~~ produced from these ancillary cutting paths. This is done by shifting the support points of the ancillary cutting paths in the direction of the normal vectors of the workpiece surface to be cut. The shift occurs by taking the radius r_S or the diameter d_S of the tool shank of the spherical cutter into account, these parameters corresponding to the radius R_S or the diameter D_S of the tool shank of the cutting tool ~~of the present invention~~ to be used. Furthermore, the shift of the support points occurs by using radius R_K of the tool head of the cutting tool ~~according to the present invention~~ and by using the radius center points of the tool heads of the spherical cutter and the cutting tool actually to be used. By a simple subtraction of the

corresponding geometric parameters, it is possible to determine the magnitude of the shift of the support points.

~~With the aid of the present invention it~~ **It** is possible ~~for the first time~~ to use cutting tools in the cutting of complex freeform surfaces on blisks, the tool heads of which have a greater radius than the tool shank of the cutting tool. This ~~allows~~ **may allow** for a greater line spacing to be set in the cutting process. The time required for cutting [[is]] **may be** reduced. The effectiveness of the cutting process [[is]] **may be** increased.

~~Abstract~~

ABSTRACT

~~The present invention relates to~~ **In** a method for cutting freeform surfaces[[.]]**, a**

[[A]] workpiece is cut by a cutting tool ~~(15) in~~ such ~~a way~~ that a desired freeform surface [[is]] **may be** achieved, the cutting tool ~~(15)~~ for cutting purposes being moved along at least one defined cutting path relative to the workpiece.

~~According to the present invention, a~~ **A** cutting tool ~~(15)~~ is used, the tool head ~~(17)~~ of which has a greater radius than a tool shank ~~(16)~~ of the cutting tool ~~(15)~~. ~~(Fig. 2)~~